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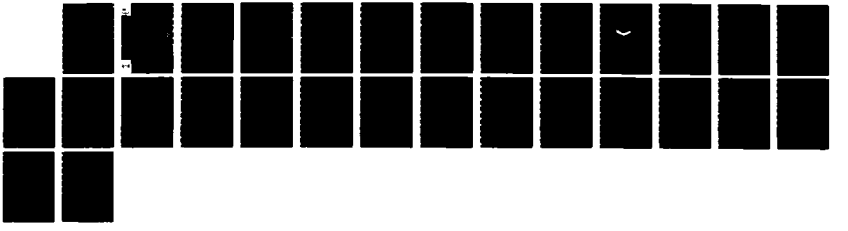

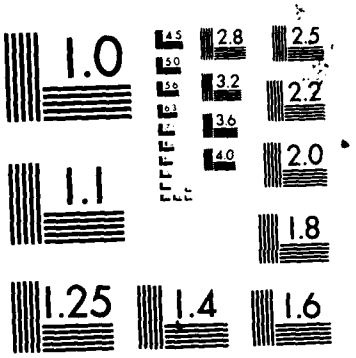

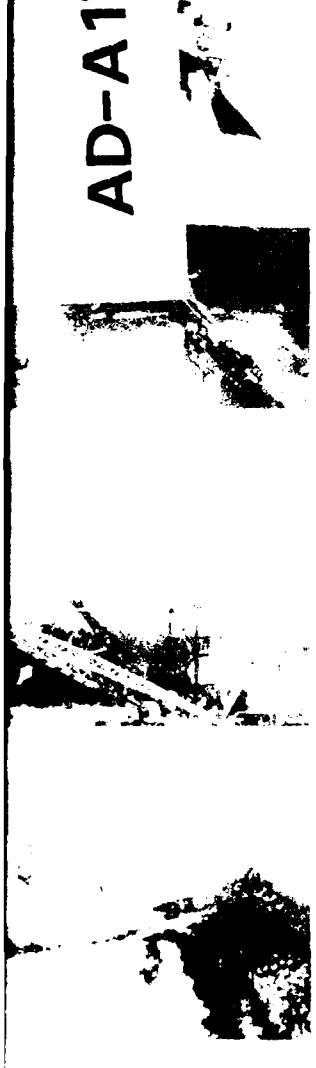

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LONG-TERM EFFECTIVENESS OF CAPPING IN ISOLATING DUTCH KILLS SEDIMENT FROM BIOTA AND THE OVERLYING WATER

by

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At the request of the New York District, the effectiveness of capping in chemically and biologically isolating contaminated dredged material over a 1-year period was investigated using large (250-ℓ) laboratory reactor units. The ability of Edgewater cap material to isolate contaminated Dutch Kills sediment was assessed by following the movement of chemical contaminants and microbial spores contained in the Dutch Kills sediment into the water column and by monitoring the biological uptake of chemical contaminants by the clam, *Mercenaria mercenaria*. At the conclusion of the year study, sediment cores were obtained from the experimental units and analyzed for chemical contaminants to determine if contaminant movement into the cap had occurred.

Results of water column, animal bioaccumulation, and core sampling indicate that capping of contaminated Dutch Kills sediment with either 10 or 50 cm of clean cap material will prevent the movement of detectable amounts of contaminants through

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the cap material. It is highly likely that the greatest value of a cap is in physically isolating contaminated dredged material from the overlying water and biota. In the absence of bioturbation or physical disturbance, core data revealed that the cap maintained its integrity over the course of a year without mixing with the contaminated sediment. Addition of a 10 cm Edgewater cap, along with a suitable thickness of material to isolate burrowing benthic organisms from the dredged material and prevent current and wave action from removing the cap, should prevent movement of contaminants into the water and biota in the field.

Preface

This study was sponsored by the US Army Engineer District, New York, and the work was conducted by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The New York District Project Managers were Messrs. James Mansky and John Tavolaro. Publication of this report was partially funded by the Dredging Operations Technical Support Program.

This study was conducted by Drs. James M. Brannon and Douglas Gunnison and Messrs. Ronald E. Hoeppel, Thomas C. Sturgis, and Issac Smith, Jr., of the Ecosystem Research and Simulation Division (ERSD). The study was conducted under the direction of Dr. John Harrison, Chief of EL, and Dr. Thomas L. Hart, Chief of the Aquatic Processes and Effects Group, and Mr. Donald L. Robey, Chief of the ERSD. This report was edited by Ms. Jamie W. Leach of the WES Information Products Division.

The Tennessee Valley Authority, Division of Services and Field Operations, Laboratory Branch, conducted the sample analysis for polychlorinated biphenyl compounds (PCBs) and the Analytical Laboratory Group, Environmental Engineering Division, EL, conducted the heavy metal and polyaromatic hydrocarbon (PAH) analyses.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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Contents

LONG-TERM EFFECTIVENESS OF CAPPING IN ISOLATING DUTCH KILLS SEDIMENT FROM BIOTA AND THE OVERLYING WATER

Introduction

Background

1. Maintenance of navigable waterways is vital to the economic well being and growth of this Nation. To maintain navigable waterways, a major function of the US Army Corps of Engineers, 200 to 250 million cubic metres of maintenance dredged material must be removed annually from harbors and channels and disposed of in a manner that is both cost-effective and environmentally compatible. The widespread urban areas surrounding New York Harbor provide little available land for upland disposal of large quantities of dredged material, while land disposal of contaminated dredged material may also be a potential source of ground-water contamination (Yu et al. 1978). In addition, when an evaluation of dredged material, a part of assessing the suitability for aquatic disposal, indicates that the potential for ecological harm exists, aquatic disposal, including ocean disposal, of that material may also be prohibited. A disposal method in open water that involves capping contaminated dredged material with clean dredged material has been advanced as a means of isolating contaminated dredged material from the overlying water and biota.

2. Capping contaminated dredged material with clean material to reduce the ecological impact of dredged material disposal in open water has been conducted on an experimental basis in the New England and New York Districts. These studies have shown that capping is technically feasible and that the caps appear to be stable under normal tide and wave conditions (O'Conner and O'Conner 1983 and Science Applications, Inc. (SAI) 1982). Laboratory studies conducted at the US Army Engineer Waterways Experiment Station (WES) during the past 3 years to evaluate the effectiveness of capping in isolating contaminated dredged material have demonstrated that capping can isolate contaminated dredged material over the short to medium term (Brannon et al. in press). It is believed, however, that capping slows, but does not prevent, the transfer of contaminants to the overlying water over a prolonged period (O'Conner and O'Conner 1983). For capping to be conducted on other than an

experimental basis, it must be demonstrated that capping will isolate the contaminated material over the long term.

Objective

3. The objective of this study was to evaluate the effectiveness of capping in isolating Dutch Kills sediment in New York Harbor from organisms and the water column over a long term (1 year). Biological testing has revealed that the potential for ecological harm exists in Dutch Kills sediment. Based on these results, ocean disposal of this material has been prohibited. Short- to medium-term testing of capping Dutch Kills sediment has revealed that capping is effective in preventing the transfer of contaminants to the water column and biota (Brannon et al. in press), but the long-term effectiveness of capping is unknown. The present long-term assessment of the effectiveness of capping in chemically and biologically isolating Dutch Kills sediment was therefore conducted.

Materials and Methods

Sediment acquisition

4. Sediment samples were obtained from the Dutch Kills channel area of New York Harbor and the Edgewater area in the Hudson River by personnel from the New York District on 2 and 3 April 1984, using a 1.5-cu-yd (1.15-cu-m) clamshell dredge. Five 208-ℓ steel barrels of sediment were obtained from each site. Samples were then placed in a refrigerated truck and transported to the WES. Upon arrival at WES, contents of the five barrels of Dutch Kills sediment and five barrels of Edgewater sediment were separately composited and mixed, then returned to the barrels for storage at 4° C.

Experimental

5. Laboratory studies to assess long-term (1-year) effectiveness of Edgewater sediment in isolating Dutch Kills sediment were conducted in a controlled environment chamber maintained at 20° ± 0.5° C, using modified 250-ℓ flow-through reactor units (Figure 1) described in detail by Gunnison et al. (1980). These chambers are 121 cm in height and measure 46 cm on a side. Modifications included sealing of sampling ports with Plexiglas, removal of the mixing pump from the system, and provision for constant aeration of the water column. With the exception of the control units, to which only Edgewater sediment was added, 17 cm of Dutch Kills sediment was first placed

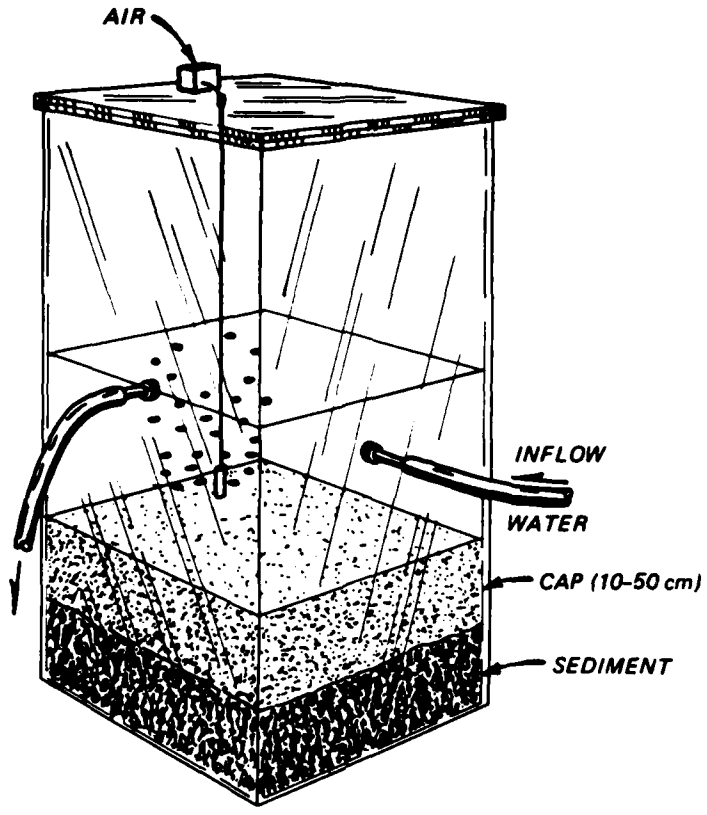

Figure 1. Flow-through reactor units

on the bottom of each reactor unit and capped with either 10 or 50 cm of Edgewater sediment. Sixty litres of artificial seawater at 20 ppt, prepared from Instant Ocean Artificial sea salts, was added as gently as possible to each reactor unit and allowed to equilibrate with aeration for 14 days. A 14-day equilibration time was selected to allow initial compaction to occur and material suspended during water addition to settle. At the end of the equilibration/consolidation period, flow through of artificial seawater was initiated at a rate of 0.2 ℓ/hr. At this flow rate, 50 percent of the overlying water was replaced in approximately 9 days (Sprague 1969). Aeration ensured constant mixing of water in the reactor units. To remove organic contaminants from inflows, all artificial seawater was passed through an activated charcoal filter prior to addition to any of the experimental units.

6.The clam (*Mercenaria mercenaria*) was used to determine if contaminants were moving through the cap and into the water column. *Mercenaria mercenaria* was also used in the previous short- to medium-term capping study involving Dutch Kills sediment. Clams were obtained from Multi-Aquaculture

Systems, Inc., Amagansett, N. Y. The clams were acclimated to test conditions in the laboratory for at least 1 week prior to being added to the reactor units. Clams were added to each experimental unit following 4 days of flow-through operation in the reactor units. Treatments included cap material alone, Dutch Kills sediment alone, and 10- and 50-cm caps of Edgewater sediment over Dutch Kills sediment. There were three replicates of each experimental treatment. Twenty-one clams were placed into a basket that was then suspended in the water column 5 cm above the sediment surface in each reactor unit. Concurrent with addition of clams to the reactor units, subsamples were removed from the holding tanks for initial chemical characterization. These clams were immediately frozen, then divided into subsamples for polychlorinated biphenyl (PCB), polyaromatic hydrocarbon (PAH), and metals analyses, removed from their shells, then placed in hexane-rinsed glass (PCB, PAH) or acid- (HCl) washed plastic (metals) containers and maintained frozen until analysis. All clams were removed from each reactor unit after 10 days of exposure and handled in the same manner as described for initial clam samples. Addition and removal of clams to the reactor units was repeated at intervals of 100, 240, and 365 days following placement of the cap material. Clams in each reactor unit were not fed during any of the exposure periods.

7. Water samples were obtained just prior to addition of the first group of clams to the reactor units, then 14, 180, and 365 days into the experiment. Samples to be used for PCB and PAH analyses were placed in 3.8-ℓ glass jars which had been hexane washed and dried at 105° C for 24 hr. Samples for metal analyses were filtered through 0.45-μm pore size membrane filters with the first 100 mℓ of filtrate discarded. The subsequent filtrate was acidified to pH 1 with concentrated nitric acid. Water samples were analyzed for Cd, Cu, Pb, and Zn using a Perkin-Elmer Model 2100 heated graphite atomizer and a Perkin-Elmer Model 503 atomic adsorption spectrophotometer. Mercury was determined using a Perkin-Elmer Model 503 atomic adsorption unit coupled to a Perkin-Elmer MHS-10 hydride generator. Unfiltered water samples were analyzed for total suspended solids using the method of Ballinger (1979).

8. Water, tissue, and sediment samples were analyzed for 10 PCB isomer groups: total monochlorobiphenyls through total decachlorobiphenyls. Isomer group concentrations were determined following soxhlet extraction, sulfuric acid cleanup, and quantification in an electron capture detector gas chromatograph.

9. Eighteen compounds comprising the PAH family of compounds (Table 1) were also determined in water, sediment, and tissue samples. Samples were soxhlet extracted overnight with benzene:methanol. The aromatic hydrocarbon fraction was then separated using silica gel chromatography, concentrated, and subjected to capillary gas chromatographic analysis on a Hewlett Packard 5985 gas chromatograph/mass spectrophotometer. Individual compounds were quantified using analytical standards and an internal standard. Lipid concentrations were determined on each tissue sample (Food and Drug Administration (FDA) 1977). Heavy metal concentrations in water, tissue, and sediment samples were analyzed using atomic absorption spectroscopy following appropriate sample digestion procedures (Ballinger 1979). Sediment particle-size distribution was determined using the method of Patrick (1958).

Sediment coring

10. Following final sampling of water and clams, core samples were obtained from experimental units with 50-cm caps by slowly pushing a 5-cm Plexiglas tube into the sediment. Following core extrusion and identification of the dredged material/cap interface, subsamples of sediment were removed for subsequent chemical and biological analysis. Samples for analyses were taken slightly below the interface in the Dutch Kills sediment (-0.5 to -2.5 cm), and above the interface in the cap material (+0.5 to +2.5 cm, +24 to +26 cm, and +46.5 to +48.5 cm). Sediment samples were placed in appropriate sample containers: glass for PCBs, plastic for metals, and autoclaved plastic containers for microbial analysis. The samples were then refrigerated at 4° C until analyzed.

Microbiological studies

11. Sediment analyses. The Dutch Kills sediment and Edgewater capping materials were assayed for ***Clostridium perfringens*** by the membrane filter (mCP) method of Bisson and Cabelli (1979) using the shake, sonication, and settling procedures previously developed and evaluated for marine sediment (Emerson 1982, Emerson and Cabelli 1982). ***Clostridium perfringens*** has proven to be a valuable tracer in previous Dutch Kills capping studies (Brannon et al. in press).

12. Water analyses. Water samples from each large reactor unit were monitered for viable ***Clostridium perfringens*** spore densities using the mCP method of Bisson and Cabelli (1979). One-tenth percent peptone water was used as the buffer solution, and incubation of mCP plates was at 44° ± 0.5° C for

18-20 hr. Water samples were assayed 2 hr before the initial clam addition and then at monthly intervals for the year duration of the study.

Analysis of results

13. Means and standard errors were determined for each parameter within a treatment. Comparisons between treatments at a sampling time and between treatments over time were conducted using procedures developed by the Statistical Analysis Systems (SAS) Institute (Barr et al. 1976). Statements of significance made in the text refer to the 5-percent level or less.

Results and Discussion

Sediment chemical characterization

14. Sediment from Dutch Kills was more contaminated with PCBs than the capping sediment from the Edgewater site (Table 2). Total PCB concentration in Dutch Kills sediment was 21.3 µg/g dry weight compared with 0.41 µg/g dry weight in Edgewater site sediments. Total hexachlorobiphenyls constituted the largest fraction of PCBs in Dutch Kills sediment (37.6 percent), but total tetrachlorobiphenyls constituted the largest fraction of PCBs in Edgewater site (39.0 percent) sediments.

15. Both sediments contained PAH compounds (Table 3); however, Dutch Kills sediment contained approximately an order of magnitude more PAHs than sediment from the Edgewater site. Dutch Kills sediment also contained higher levels of heavy metals compared with Edgewater site sediment (Table 4). Mercury showed the least concentration differential between Edgewater and Dutch Kills sediment, but was still five times higher in Dutch Kills sediment compared with Edgewater sediment. Dutch Kills sediment also contained more clay and less silt than Edgewater sediment.

Contaminant release and uptake

16. Concentration values for selected contaminants were determined in water and clams to assess the ability of 10- and 50-cm Edgewater sediment caps to isolate Dutch Kills sediment for 1 year. The clams did not suffer excessive mortality in the reactor units; 95 percent or more of the animals added initially to the experimental units survived until sampled and used for tissue analyses.

17. Water column. Heavy metal (Table 5) and PCB isomer group (Table 6) concentrations in the water column above capped sediments did not

significantly differ from their respective concentrations in the Edgewater site water column during any of the four sampling periods.

18. Replicate samples for PAHs in the water column were composited to obtain greater sensitivity. This procedure precludes statistical analysis, but does give an indication of trends in the data. As shown in Table 7, total PAH concentrations were generally less than 1 µg/ℓ and showed no clear trend among treatments. These data indicate that the Edgewater site cap prevented water column contamination attributable to Dutch Kills sediment during the year of this study.

19. Suspended sediment concentrations in the water column were low and did not differ among treatments at any of the sampling times, averaging 4.3 mg/ℓ. The lack of suspended solids was due to the absence of bioturbation in the experimental units and can account for the low levels of PAH and PCB compounds in the water column. Similar results could be expected in the field if sufficient cap material is added to prevent burrowing organisms from reaching the contaminated dredged material.

20. *Mercenaria mercenaria.* Tissue concentrations of PCB and PAH are reported on a wet weight basis and have not been normalized to lipid concentration for the following reasons. First, the concentrations of PCB and PAH compounds in the *Mercenaria mercenaria* tissue were low, with all PCB concentrations below detection limits. Secondly, clam lipid concentrations were very low with minor variation between batches (Table A1). Concentrations can be converted to a lipid normalized concentration by dividing the percent lipid values in Table A1 by 100, then dividing the wet weight PAH or PCB concentration by this number.

21. Heavy metal concentrations in *Mercenaria mercenaria* tissue did not significantly exceed that of Edgewater site cap material in any of the treatments or sampling times (Table 8). These results are not surprising since the interstitial water heavy metal concentrations (Table 9) were similar for both Dutch Kills and Edgewater sediments. Therefore, even if compaction of the capped Dutch Kills sediment resulted in all the interstitial water being squeezed through the cap material with no adsorption of heavy metals by the cap material, there would still not be a substantial change in heavy metal mobilization into the overlying water. Metals should therefore pose no problems to the overlying water and biota. Due to the highly variable initial

contaminant values for clams (Table A2), no attempt was made to compare treatment values over time.

22. PAH concentrations in clams did not significantly exceed those observed in Edgewater cap material for any of the capped treatments (Table 10). In addition, PCB concentrations were below detection limits (<0.01 µg/g wet weight) in clam tissue in all treatments at all sampling times.

23. These results indicate that, over a 1-year period, either a 10- or 50-cm cap of Edgewater sediment effectively isolated *Mercenaria mercenaria* and the overlying water from contaminants contained in the Dutch Kills sediment. These studies were conducted in the absence of bioturbation, but if sufficient cap material is emplaced to allow for the depth of bioturbation, there is no reason to expect that results in the presence of bioturbation would differ substantially from those reported here. Contaminants would still need to diffuse from the Dutch Kills sediment into the cap and move from there into the zone where the bioturbators are functioning. As demonstrated in this study, measurable movement of contaminants out of the Dutch Kills sediment and through a cap were not observed over the course of a year, even when only a 10-cm cap was present.

24. Microbial releases. The *Clostridium perfringens* membrane filter (mCP) assays of the Dutch Kills sediment indicated that very high numbers of viable cells and/or spores (1,010,000/g dry sediment) are present (Brannon et al. 1985). The Edgewater cap material contained considerably lower numbers of *Clostridium perfringens*, averaging 1,700 viable cells and/or spores/g dry sediment. *Clostridium perfringens* is a fecal pollution indicator and pathogenic bacterium as well as a strict anaerobe; i.e., it does not grow under aerobic conditions (Bisson and Cabelli 1979). Therefore, monitoring of viable *Clostridium perfringens* spore densities in the aerated water column of the test chambers could serve to evaluate the movement of very small discrete particles through the Edgewater cap material covering the Dutch Kills sediment. Endospores of clostridia are less than 1 µ in diameter, smaller than most bacteria and very fine clay-sized particles, and do not germinate and grow at temperatures less than 20° C (Gramberg 1983).

25. Spore counts of *Clostridium perfringens* in the water column of reactor units containing only Dutch Kills sediment greatly exceeded spore counts in waters overlying the cap material alone or in waters overlying capped Dutch Kills sediment (Table 11). There was no significant difference between

treatments containing cap material alone and either of the capped treatments. These data indicate that the cap material effectively sealed the contaminated Dutch Kills sediment from the overlying water over a 1-year period.

Core sampling

26. Analysis of sediment core contaminant concentration results (Table 12) indicated that following 1 year of cap emplacement in the laboratory, contaminants had not migrated into the Edgewater cap from the Dutch Kills sediment in measurable quantities. There was a sharp demarcation between the Dutch Kills sediment and the Edgewater cap material. Lead concentrations, for example, decreased from 945 to 40 µg/g when crossing the Dutch Kills/ Edgewater sediment interface. Migration of contaminants into the Edgewater cap material did not occur despite the high sediment concentration differences between the Edgewater and Dutch Kills sediment. This is to be expected because most of the contaminants in the Dutch Kills sediment are strongly associated with the sediment and are unavailable for migration into the cap. This was demonstrated by the interstitial water metal concentrations given in Table 12.

Summary and Conclusions

27. Results of water column, animal bioaccumulation, and core sampling indicate that capping of contaminated Dutch Kills sediment with clean cap material will prevent the movement of detectable amounts of contaminants through the cap material. This was found to hold true over the course of a year of sampling in the laboratory. Analysis of interstitial water metal concentrations showed that the Dutch Kills sediment and Edgewater cap material possessed very similar concentrations despite the large differences in total metal concentration in the sediments. This would also be expected to hold true for organic contaminants in the interstitial water. Due to these low interstitial water concentrations, compaction of the Dutch Kills sediment and squeezing of the interstitial water through the cap material, even with no contaminant adsorption by the cap material, would not substantially affect the overlying water contaminant concentrations.

28. It appears that the greatest value of a cap is in physically isolating contaminated dredged material from the overlying water and biota. As shown by the core data, the cap maintained its integrity over the course of

a year without mixing with the contaminated sediment. Additionally, in the absence of bioturbation, even the contaminated Dutch Kills sediment did not increase contaminant concentrations in the water column and in ***Mercenaria mercenaria*** to higher levels than those measured in Edgewater sediment.

29. Results of this study, coupled with results of a previous study of capping Dutch Kills sediment (Brannon et al. in press), have demonstrated that capping will prevent the movement of contaminants into the water column and biota over the short, medium, and long term. Addition of a 10-cm cap of Edgewater sediment along with a suitable depth of material to isolate burrowing benthic organisms from the dredged material and prevent current and wave action from removing the cap should prevent movement of contaminants into the water and biota in the field.

References

Ballinger, D. C. 1979. "Methods for Chemical Analysis of Water and Wastes," EPA 600/4-79-020, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Bisson, J. W., and Cabelli, V. J. 1979. "Membrane Filter Enumeration Method for *Clostridium perfringens*," Applied Environmental Microbiology, Vol 37, No.1, pp 55-66.

Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T. 1976. "A Users Guide to SAS 76," Statistical Analysis Systems Institute Inc., Raleigh, N. C.

Brannon, J. M., et al. In Press. "Effectiveness of Capping in Isolating Dutch Kills Sediment From Biota and the Overlying Water," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Brannon, J. M., et al. 1985. "Effectiveness of Capping in Isolating Contaminated Dredged Material from Biota and the Overlying Water," Technical Report D-85-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Emerson, D. J. 1982. "The Monitoring of *Clostridium perfringens* Spore Density in Bottom Sediments and Its Applications," M.S. Thesis, University of Rhode Island, Kingston, R. I.

Emerson, D. J., and Cabelli, V. J. 1982. "Extraction of *Clostridium perfringens* Spores from Bottom Sediment Samples," Applied Environmental Microbiology, Vol 44, No. 5, pp 1144-1149.

Food and Drug Administration. 1977. "Pesticide Analytical Manual, Volume 1, Methods for Individual Pesticides," US Department of Health and Human Services, Washington, DC.

Gramberg, K. 1983. "*Clostridium perfringens* (Holland) as an Indicator of Human Effluent in the Sediment of Lake Tuomiojarve, Central Finland," Hydrobiologia, Vol 103, pp 181-184.

Gunnison, D., Brannon, J. M., Smith, I., Jr., Burton, G. A., Jr., and Preston, K. M. 1980. "A Reaction Chamber for Study of Interactions Between Sediments and Water Under Conditions of Static or Continuous Flow," Water Research, Vol 14, pp 535-543.

O'Connor, J. M., and O'Connor, S. G. 1983. "Evaluation of the 1980 Capping Operations at the Experimental Mud Dump Site, New York Bight Apex," Technical Report D-83-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Patrick, W. H., Jr. 1958. "Modification of Method of Particle Size Analyses," Proceedings of the Soil Science Society of America, Vol 4, pp 366-367.

Science Applications, Inc. 1982. "DAMOS Progress Report to US Army Engineers, New England District," Science Applications, Inc., Newport, R. I.

Sprague, J. B. 1969. "Measurement of Pollutant Toxicity to Fish, 1. Bioassay Methods for Acute Toxicity," Water Research, Vol 3, pp 793-821.

Yu, K. Y., Chen, K. Y., Morrison, R. D., and Mang, J. L. 1978. "Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas," Technical Report D-78-43, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Table 1

Polyaromatic Hydrocarbon Compounds Determined in Water and Tissue Samples

Two-Ring Compounds	Three-Ring Compounds
Naphthalene	Fluorene
Benzothiophene	Dibenzothiophene
2-methylnaphthalene	Phenanthrene
1-methylnaphthalene	Anthracene
Biphenyl	1-methylphenanthrene
2,6-dimethylnaphthalene	Fluoranthene
2,3,6-trimethylnapthalene	
Four-Ring Compounds	**Five-Ring Compounds**
Pyrene	Benzo(e)Pyrene
Chrysene	Benzo(a)Pyrene
	Perylene

Table 2

Sediment PCB Concentrations

Isomer Group	PCB Concentration in Sediment, µg/g dry weight	
	Dutch Kills	Edgewater Cap
Total monochlorobiphenyls	0.98	<0.5
Total dichlorobiphenyls	2.1	0.08
Total trichlorobiphenyls	2.0	0.08
Total tetrachlorobiphenyls	3.7	0.16
Total pentachlorobiphenyls	2.8	<0.01
Total hexachlorobiphenyls	8.0	0.06
Total heptachlorobiphenyls	0.71	0.01
Total octachlorobiphenyls	0.86	0.01
Total nonachlorobiphenyls	0.11	0.01
Total decachlorobiphenyls	0.03	<0.01
Total PCBs	21.29	0.41

Table 3

Sediment PAH Concentrations

Parameter	PAH Concentration in Sediment, µg/g Sediment dry weight	
	Dutch Kills	Edgewater Cap
Naphthalene	2.95	0.25
Benzothiophene	0.55	ND*
2-methylnaphthalene	5.99	0.11
1-methylnaphthalene	3.18	0.01
Biphenyl	2.40	0.18
2,6-dimethylnaphthalene	7.46	0.11
2,3,6-trimethylnaphthalene	5.67	0.008
Fluorene	6.55	0.19
Dibenzothiophene	7.24	0.11
Phenanthrene	18.6	1.03
Anthracene	8.12	0.40
1-methylphenanthrene	7.33	0.37
Fluoranthene	6.63	2.02
Pyrene	ND	1.84
Chrysene	ND	ND
Benzo(e)Pyrene	2.26	0.45
Benzo(a)Pyrene	2.84	0.69
Perylene	1.11	1.62
Total PAHs	88.88	9.39

* ND = not detected (detection limits of 3 ng/g).

Table 4

Heavy Metal Concentrations and Selected Sediment Physical Characteristics

Sediment	Metal Concentration, µg/g dry weight					Texture, % Sand:Silt:Clay
	Cd	Cu	Pb	Hg	Zn	
Dutch Kills	97	1,925	1,430	0.54	2,400	40:30:30
Edgewater cap	0.4	43	43	0.10	98	43:40:17

Table 5

Heavy Metal Concentrations in Water

Treatment	Concentration, µg/ℓ (SE)*				
	Cd	Cu	Pb	Hg	Zn
Time = 0 days					
Control	1.6 (0.15)	5.7 (2.8)	<1	<0.2	37.7 (37.7)
10-cm cap	1.6 (0.15)	7.3 (4.1)	<1	<0.2	37.7 (37.7)
50-cm cap	1.4 (0.03)	5.3 (0.7)	<1	<0.2	12.0 (12.0)
Dutch Kills	1.4 (0.03)	5.7 (3.5)	<1	<0.2	43.0 (24.8)
Inflow	1.5	4.0	<1	<0.2	<30
Time = 14 days					
Control	2.3 (0.6)	6.0 (1.5)	99 (9)	<0.2	62 (47)
10-cm cap	1.8 (0.1)	8.7 (4.2)	103 (2)	<0.2	<30
50-cm cap	1.8 (0.03)	4.7 (0.3)	97 (6)	<0.2	<30
Dutch Kills	1.8 (0.0)	5.0 (0.0)	88 (17)	<0.2	81 (13)
Inflow	1.7	6.0	121	<0.2	33
Time = 180 days					
Control	4.6 (0.7)	4.3 (0.3)	3.7 (2.0)	<0.2	<30
10-cm cap	3.2 (0.4)	3.3 (0.3)	7.7 (1.8)	<0.2	<30
50-cm cap	5.9 (1.7)	4.7 (0.9)	10.3 (2.7)	<0.2	<30
Dutch Kills	6.9 (0.6)	6.0 (1.0)	5.3 (3.5)	<0.2	<30
Inflow	6.8	6.0	13	<0.2	<30
Time = 365 days					
Control	48 (3.3)	2.3 (0.3)	14 (3.5)	<0.2	51 (8)
10-cm cap	51 (3)	1.6 (3.3)	16 (2.4)	<0.2	61 (10)
50-cm cap	57 (20)	2.0 (0.0)	13 (2.9)	<0.2	49 (1)
Dutch Kills	66 (26)	2.3 (0.3)	13 (4.0)	<0.2	87 (44)
Inflow	54	<1	43	<0.2	41

* SE = standard error.

Table 6

PCB Concentrations in Water

Parameter	Concentration, µg/ℓ (SE)*				
	Control	10-cm cap	50-cm cap	Dutch Kills	Inflow
Time = 0 days					
Monochlorobiphenyls	<0.5	0.17 (0.17)	0.25 (0.25)	0.22 (0.22)	<0.5
Dichlorobiphenyls	<0.01	<0.01	<0.01	<0 01	<0.01
Trichlorobiphenyls	<0.01	<0.01	0.02 (0.02)	<0.01	<0.01
Tetrachlorobiphenyls	0.01 (0.02)	0.08 (0.05)	0.01 (0.01)	0.01 (0.01)	<0.01
Pentachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorobiphenyls	<0.01	0.01 (0.01)	<0.01	<0.01	<0.01
Heptachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Octachlorobiphenyls	0.01 (0.01)	<0.01	<0.01	0.01 (0.01)	0.01
Nonachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Decachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Total PCBs	0.02 (0.02)	0.26 (0.13)	0.28 (0.23)	0.24 (0.23)	0.01
Time = 14 days					
Monochlorobiphenyls	<0.5	<0.01	<0.5	<0.5	<0.5
Dichlorobiphenyls	0.02 (0.02)	<0.01	<0.01	<0.01	<0.01
Trichlorobiphenyls	<0.01	0.08 (0.06)	<0.01	<0.01	<0.01
Tetrachlorobiphenyls	0.02 (0.02)	0.11 (0.06)	0.04 (0.04)	0.02 (0.02)	0.01
Pentachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Heptachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Octachlorobiphenyls	0.01 (0.00)	0.01 (0.00)	0.01 (0.01)	0.01 (0.01)	0.01
Nonachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Decachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Total PCBs	0.05 (0.02)	0.20 (0.12)	0.05 (0.04)	0.03 (0.02)	0.02
Time = 180 days					
Monochlorobiphenyls	<0.5	<0.5	<0.01	<0.5	<0.5
Dichlorobiphenyls	0.05 (0.02)	0.05 (0.00)	0.06 (0.01)	<0.01	0.11
Trichlorobiphenyls	0.14 (0.04)	0.14 (0.01)	0.13 (0.01)	0.07 (0.02)	0.18
Tetrachlorobiphenyls	0.04 (0.01)	0.05 (0.01)	0.05 (0.01)	0.03 (0.00)	0.05
Pentachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorobiphenyls	0.01 (0.01)	0.02 (0.01)	0.03 (0.01)	0.01 (0.00)	0.03
Heptachlorobiphenyls	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	<0.01	0.01
Octachlorobiphenyls	0.01 (0.00)	<0.01	<0.01	<0.01	<0.01
Nonachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Decachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Total PCBs	0.26 (0.08)	0.27 (0.04)	0.27 (0.05)	0.11 (0.02)	0.38
Time = 365 days					
Monochlorophenyls	<0.5	<0.5	<0.5	<0.5	<0.5
Dichlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Trichlorobiphenyls	0.10 (0.02)	0.10 (0.03)	0.16 (0.02)	0.11 (0.03)	0.27
Tetrachlorobiphenyls	0.06 (0.01)	0.05 (0.01)	0.05 (0.01)	0.05 (0.01)	0.05
Pentachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorobiphenyls	0.01 (0.00)	<0.01	<0.01	0.01 (0.00)	0.01
Heptachlorobiphenyls	<0.01	0.01 (0.00)	0.01 (0.00)	<0.01	0.01
Octachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Nonachlorobiphenyl	<0.01	<0.01	<0.01	<0.01	<0.01
Decachlorobiphenyls	<0.01	<0.01	<0.01	<0.01	<0.01
Total PCBs	0.17 (0.01)	0.20 (0.06)	0.22 (0.03)	0.18 (0.03)	0.34

* SE = standard error.

Table 7

Water Column PAH Concentrations

Treatment	Concentration, µg/ℓ Two-Ring Compounds	Three-Ring Compounds	Four-Ring Compounds	Five-Ring Compounds	Total PAHs
Time = 0 days					
Control	0.24	0.09	<0.005	<0.005	0.33
10-cm cap	0.16	0.38	0.095	<0.005	0.64
50-cm cap	0.22	0.16	0.007	<0.005	0.39
Dutch Kills	0.024	0.047	0.008	<0.005	0.08
Inflow	0.17	0.053	<0.005	<0.005	0.22
Time = 14 days					
Control	Sample Lost During Analytical Procedure				
10-cm cap	0.21	0.22	0.011	<0.005	0.44
50-cm cap	Sample Lost During Analytical Procedure				
Dutch Kills	0.20	0.41	0.43	<0.005	1.04
Inflow	0.18	0.44	0.26	<0.005	0.88
Time = 180 days					
Control	0.95	1.65	0.14	0.16	2.90
10-cm cap	<0.005	0.27	<0.005	<0.005	0.27
50-cm cap	Sample Lost During Analytical Procedure				
Dutch Kills	0.21	0.50	0.17	0.07	0.95
Inflow	Sample Lost During Analytical Procedure				
Time = 365 days					
Control	Sample Lost During Analytical Procedure				
10-cm cap	0.23	0.06	0.03	0.14	0.33
50-cm cap	2.25	1.0	0.26	<0.005	3.51
Dutch Kills	Sample Lost During Analytical Procedure				
Inflow	0.21	0.05	0.007	<0.005	0.27

Table 8

Heavy Metal Concentration in *Mercenaria mercenaria* Tissue

Treatment	Concentration, µg/g dry weight (SE)*				
	Cd	Cu	Pb	Hg	Zn
			Time = 10 days		
Control	1.38 (0.5)	27.9 (2.3)	4.39 (0.3)	<0.1	120 (24)
10-cm cap	0.73 (0.1)	26.3 (1.1)	5.04 (1.8)	<0.1	91 (6)
50-cm cap	0.68 (0.1)	25.9 (1.9)	5.73 (1.5)	<0.1	90 (3)
Dutch Kills	1.81 (0.2)	30.9 (2.6)	5.47 (0.2)	<0.1	142 (6)
			Time = 100 days		
Control	1.86 (0.3)	27.1 (1.3)	3.48 (0.6)	<0.1	140 (10)
10-cm cap	1.75 (0.1)	25.9 (1.4)	2.60 (0.3)	<0.1	128 (11)
50-cm cap	1.78 (0.5)	27.4 (1.5)	3.29 (0.2)	<0.1	132 (4)
Dutch Kills	1.71 (0.1)	27.7 (3.1)	3.74 (0.4)	<0.1	145 (2)
			Time = 240 days		
Control	0.80 (0.1)	23.2 (1.9)	3.06 (0.4)	<0.1	115 (12)
10-cm cap	0.95 (0.2)	24.7 (1.8)	4.27 (0.6)	<0.1	120 (10)
50-cm cap	1.11 (0.2)	29.0 (0.8)	6.57 (2.0)	<0.1	147 (23)
Dutch Kills	0.89 (0.2)	23.4 (5.1)	3.37 (0.3)	<0.1	120 (17)
			Time = 365 days		
Control	2.01 (0.2)	25.9 (5.7)	4.49 (0.8)	<0.1	97 (8)
10-cm cap	1.76 (0.1)	21.6 (2.9)	5.19 (0.1)	<0.1	122 (10)
50-cm cap	1.53 (0.1)	17.6 (0.7)	4.72 (0.7)	<0.1	102 (6)
Dutch Kills	1.61 (0.1)	20.7 (2.0)	6.12 (0.9)	<0.1	109 (14)

* SE = standard error.

Table 9

Interstitial Water Heavy Metal Concentrations

Sediment	Concentration, mg/ℓ				
	As	Cd	Cr	Pb	Zn
Dutch Kills	<0.005	<0.0001	0.007	0.030	0.072
Edgewater	0.008	<0.0001	0.005	0.005	0.032

Table 10

PAH Concentrations in *Mercenaria mercenaria*

Treatment	Concentration, µg/g Wet Weight (SE)*				
	Two-Ring Compounds	Three-Ring Compounds	Four-Ring Compounds	Five-Ring Compounds	Total PAH
Time = 10 days					
Control	0.04 (0.02)	0.09 (0.05)	0.07 (0.03)	0.02 (0.02)	0.22 (0.11)
10-cm cap	0.04 (0.03)	0.02 (0.01)	0.04 (0.02)	<0.01	0.10 (0.05)
50-cm cap	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	<0.01	0.03 (0.00)
Dutch Kills	0.04 (0.01)	0.11 (0.02)	0.11 (0.03)	0.05 (0.02)	0.31 (0.08)
Time = 100 days					
Control	0.02 (0.01)	0.02 (0.02)	<0.01	<0.01	0.04 (0.01)
10-cm cap	0.02 (0.01)	0.01 (0.01)	<0.01	<0.01	0.03 (0.02)
50-cm cap	0.01 (0.01)	0.01 (0.01)	<0.01	<0.01	0.02 (0.01)
Dutch Kills	0.01 (0.00)	<0.01	<0.01	<0.01	0.01 (0.00)
Time = 240 days					
Control	0.02 (0.00)	0.04 (0.02)	0.06 (0.01)	0.01 (0.01)	0.13 (0.02)
10-cm cap	0.02 (0.01)	0.04 (0.01)	0.05 (0.02)	0.01 (0.01)	0.11 (0.03)
50-cm cap	0.02 (0.01)	0.04 (0.01)	0.05 (0.02)	0.02 (0.01)	0.13 (0.03)
Dutch Kills	0.04 (0.01)	0.02 (0.01)	0.03 (0.00)	<0.01	0.09 (0.01)
Time = 365 days					
Control	0.02 (0.00)	0.01 (0.01)	0.02 (0.01)	<0.01	0.05 (0.02)
10-cm cap	0.02 (0.00)	0.02 (0.01)	0.01 (0.01)	<0.01	0.05 (0.01)
50-cm cap	0.03 (0.01)	0.03 (0.00)	0.02 (0.01)	<0.01	0.08 (0.02)
Dutch Kills	0.03 (0.01)	0.02 (0.00)	0.04 (0.01)	0.01 (0.00)	0.10 (0.01)

* SE = standard error.

Table 11

Clostridium perfringens Bacterial Spore Counts in Chamber Water Samples

Sampling Time, days	Spore Count in Indicated Treatment, No./100 mℓ (SE)*			
	Control	10-cm Cap	50-cm Cap	Dutch Kills
9	<1	<1	<1	65 (17)
17	<1	2 (0.15)	1 (0.6)	65 (20)
29	<1	2 (0.5)	<1	40 (5)
44	<1	<1	1 (0.2)	34 (7)
58	1 (1)	2 (2)	1 (1)	35 (11)
80	<1	<1	<1	13 (8)
115	<1	1 (0.6)	<1	22 (5)
150	<1	<1	<1	5 (4)
185	<1	<1	<1	14 (4)
220	<1	<1	<1	32 (5)
290	<1	<1	<1	15 (4)
346	<1	<1	<1	6 (3)

* SE = standard error.

Table 12

Clostridium perfringens Bacterial Spore Counts and Chemical Contaminant Concentrations in Sediment Cores From Reactor Vessels Containing Dutch Kills Sediment and a 50-cm Edgewater Cap

Parameter	Values for Indicated Core Segment, cm from Cap/Dutch Kills Interface			
	-0.5 to -2.5	+0.5 to +2.5	+24 to +26	+46.5 to +48.5
Clostridium perfringens, No./g dry weight (SE)*	802,200 (127,700)	4,400 (430)	4,780 (1,370)	4,760 (1,160)
Cd, µg/g dry weight (SE)	92 (0.8)	0.4 (0.1)	0.5 (0.2)	0.9 (0.3)
Cu, µg/g dry weight (SE)	1,820 (90)	50 (8)	45 (10)	48 (17)
Pb, µg/g dry weight (SE)	945 (26)	40 (6)	44 (8)	52 (8)
Hg, µg/g dry weight (SE)	0.5 (0.04)	0.09 (0.005)	0.08 (0.00)	0.04 (0.005)
Zn, µg/g dry weight (SE)	2,395 (115)	66 (35)	98 (3)	117 (33)

* SE = standard error.

Appendix A: Tissue Results

Table A1

Percent Lipids in *Mercenaria mercenaria* Tissue

Treatment	Percent Lipids* at Indicated Time, days			
	10	100	240	365
Control	0.07 (0.02)	0.09 (0.03)	0.05 (0.01)	0.08 (0.04)
10-cm cap	0.10 (0.02)	0.05 (0.01)	0.03 (0.01)	0.11 (0.03)
50-cm cap	0.06 (0.03)	0.06 (0.02)	0.05 (0.003)	0.07 (0.003)
Dutch Kills	0.12 (0.01)	0.09 (0.02)	0.02 (0.01)	0.07 (0.01)

* Wet weight (standard error(SE)).

Table A2

Contaminant Concentrations in *Mercenaria mercenaria* Prior to Addition to the Various Treatments

Parameter	Concentration at Indicated Time, days			
	0	100	240	365
Cd, µg/g dry weight	0.75	1.15	0.94	1.70
Cu, µg/g dry weight	23.4	23.3	26.3	23.5
Pb, µg/g dry weight	4.03	10.2	5.7	7.05
Hg, µg/g dry weight	0.1	<0.1	<0.1	<0.1
Zn, µg/g dry weight	86.3	112	140	104
Total PCB, µg/g wet weight	<0.01	<0.01	<0.01	<0.01
Total PAH, µg/g wet weight	0.03	0.04	0.12	0.02

Note: PCB = polychlorinated biphenyls; PAH = polyaromatic hydrocarbons.

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